Executive Summary

Neutrinoless Double Beta Decay

Summary statements

1. Neutrinoless double beta decay is our most promising technique for determining the overall scale of neutrino mass. Recent neutrino oscillation results provide compelling arguments for new experiments with 100-fold increases in sensitivity.

2. Several promising experiments using distinct technologies have reached an advanced stage of development. Because the ultimate sensitivity of new techniques is difficult to anticipate, more than one next-generation experiment must be supported.

Summary

Recent oscillation results have determined neutrino mass differences, but not the overall scale of neutrino mass crucial to both particle physics and cosmology. While next generation tritium endpoint experiments may be able to probe masses of about 0.3 eV, neutrinoless double beta decay is the only tool for reaching 0.01 eV, the level suggested by many oscillation scenarios. Neutrinoless double beta decay tests the charge conjugation properties of neutrinos, new CP violating phases, and a variety of beyond-the-standard-model phenomena.

The 0.01 eV goal requires sensitivity to half lives in excess of 10^{28} years. This in turn requires source masses ~1000 kg and unprecedented suppression of cosmic ray and radioactivity backgrounds. Several of the most promising experiments need enriched isotopes. Thus the scale and cost of future experiments are significant.

In Europe two promising experiments are Cuore, a bolometric detector using natural Te, and Genius, a germanium diode detector. Construction of prototypes for these experiments is underway. Both will be sited at Gran Sasso. Three experiments under consideration in the US are Majorana, EXO, and Moon. Majorana is an array of individually cooled enriched Ge counters with a total ^{76}Ge mass of 500 kg. Crystal segmentation and pulse-shape analysis is used to suppress backgrounds. EXO will employ 10 tons of Xe, enriched to 80% in ^{136}Xe,in a high-resolution TPC. Spectroscopic single ion tagging of the daughter Ba ion will provide additional background suppression. Moon, a joint Japanese/US effort, is a Mo foil/scintillator sandwich with a mass in ^{100}Mo in excess of 1 ton. An alternative design, a Mo-loaded scintillator, is also under discussion.

Depth and other requirements

These next-generation experiments vary in their depth requirements according to the specificity of the signals employed. Current Ge experiments indicate that Majorana will require depths in excess of 4000-4500 mwe. Estimates for EXO are 2000 mwe, though the proponents intend to verify background rates in a prototype experiment before selecting a final site. Estimates for Moon, which also detects solar neutrinos, are 4000 5000 mwe, with cosmic ray production of ^{91}Mo being troublesome.

Over the past 40 years experimental sensitivities have improved by about a factor of 10 every eight years. Thus, beyond the Majorana/EXO/Moon decade, progress will require further background improvements. If cosmic ray backgrounds are mitigated by depth alone, the need will be an additional 1600 mwe each decade.

Next-generation experiments require modest floor space (~250-500 m^2), careful attention to ventilation, low-level counting facilities, and, in certain cases, facilities for fabricating or storing materials deep underground.